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SOME RELATIONS OF METEOROLOGICAL VARIABLES TO DAY-TO-DAY FLUCTUATIONS IN SUBJECTIVE FEELING

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This research note is a report of an exploratory study pertaining to effects of weather conditions on behavior which is strategically a part of a broad program designed to identify and investigate the effects of stimuli, characteristic of the physical and social environment, that account for variance in behavior additional to that predicted by measures of individual differences, such as, aptitudes, interests, attitudes, and personality traits. The general hypothesis is that the total variance of a given response is accounted for by three sets of factors: (a) individual differences in the personality and ability characteristics of the respondents, (b) the physical and social aspects of the environment, (c) the interaction of individual differences and environmental variables.

In a real-life setting, as distinct from the isolated situation of the psychological laboratory, the natural aspects of the environment can be said to exercise a profound influence on the everyday behavior of most, if not all, living organisms. The terrain on which the organism dwells: mountains, valleys, deserts, coasts; the natural resources available in the particular environment: minerals, timber, vegetation, fish and game; and the weather in that locality: berometric pressure, temperature, humidity, winds, snowfall, seasonal changes, sudden and extreme variation in weather conditions, are all important aspects of the total stimulus situation that should not be gainsaid in analyzing the variance of individual and species behavior (Sells, 1963).

Muecher and Ungeheuer (1961) have indicated that the psychophysiological function of an organism can be influenced by two types of weather conditions: (a) periodic changes, such as diurnal, seasonal, and annual variations in weather brought about mainly by solar radiation, and (b) aperiodic changes (advective fluctuations), such as abrupt air mass movements. They state that a "stress reaction" is expected of an organism whenever advective weather conditions and local rhythmic

changes are in conflict. Thus, excessive fluctuations in diurnal variations as well as advective changes of weather should be considered stressors with which an organism cannot fully cope. As a result of such conditions, decrements and deteriorations of sensory processes and behavior eventuate.

The effects of changes in nature on the physiological and psychological state of lower organisms have received considerable attention from ethologists; yet, in the realm of psychology, experimental psychologists have persistently behaved as though they were oblivious to these realities of behavior.

Some psychologists and physiologists have investigated the diurnal metabolic rhythms of organisms. The information provided by these studies, however, is peripheral to the basic question of how the behavior of the organism is affected by gradual or sudden change in meteorological, geophysical, and climatological conditions.

Ethologists have probed the periodic and rhythmic changes in nature that bear relationships to the cyclic behavior of organisms. Brown and Webb, as reported by Thorpe (1961), found the diurnal rhythm of chromatophores (cells responsible for change in body color) in the fiddler crab to be sensitive to changes in temperature and illumination. The chromatophore rhythm of the fiddler crab has also been found to be sensitive to cosmic rays. As fluctuations in the intensity of cosmic ray showers are associated with changes in barometric pressure, it would be plausible to surmise that changes in barometric pressure bear a relationship to the physiological rhythms of the fiddler crab (Thorpe, 1961).

Nelson, as reported by Brown, et. al. (1956), suggested an association between tidal rhythms and the opening of the valves of the oyster for food intake. Brown, et. al. (1956) found the daily opening and closing activity cycle of oysters (Ostrea Virginica) and quahogs (Venus Mercenaria) to correlate with changes in barometric pressure. The 27-day activity cycle exhibited by oysters and quahogs was observed to correspond to the lunar cycle and the rotation of the sun around its axis which are phenomena known to be related to barometric pressure, possibly through the intermediation of cosmic rays.

Brown and his collaborators have also found correlations between rate and direction of changes in barometric pressure and the oxygen consumption of plants and lower animals, such as carrots, potatoes, worms, snails, and crabs. Bush (1963) reported seasonal variations in the weight, liver composition, lipids, and ovary size of the toad. During long photoperiods toads ate more insects than during short photoperiods. Segal (1963) found the development of a particular hernia in the slug to be dependent on temperature during the incubation period.

Although rhythmical changes in nature such as tides, alternation of night and day, lunar and solar cycles, and seasonal changes have been found to correlate with the periodic and phasic activities of plants and lower organisms, and even though these forms of life have been observed to react to changes in nature that do not exhibit smooth and regular periodicities (barometric pressure), it would be presumptuous to assert, without extensive empirical investigation, that metabolic rhythms and behavior in higher forms of animal life bear definite relationships to periodicities in nature.

Moreover, a substantial number of studies with lower forms of life show that not all forms of cyclical activity in animals are regulated by exogenous factors. Indeed, many of the rhythmic behavioral patterns exhibited by insects and invertebrates are endogenous and probably depend on a variety of internal pacemakers, neural or hormonal, the exact nature of which remains unspecified at the present. Thus, for example, it has been found that the daily rhythm of bees can be maintained in salt mines where presumably the insects are shielded from cosmic rays (Thorpe, 1961). Harker (1953) demonstrated that the 24-hour rhythm of activity of the May fly nymphs remained unchanged after three months of continuous exposure to light. Welsh (1941) found the diurnal changes of the pseudopupil of the crayfish to be insensitive to changes in temperature.

It may well be the case that some species are more responsive to meteorological and geophysical changes in nature (light, temperature, cosmic showers, magnetic storms, humidity, barometric pressure) than others which are more

dependent on endogenous mechanisms for the regulation of their behavior. For example, the cyclical behavior of the fiddler crab (Uca) seems to be more sensitive to environmental changes than the rhythmic activity of the crayfish (Cambarus Bartoni).

It is also well known that certain psychophysiological behaviors, i.e., sexual activity, migration, rhythm of digestive organs, sleep, hibernation, are more sensitive to changes in nature, while other organismic activities, such as brain waves and heart beat, have not been demonstrated to bear any relationship to meteological and climatological changes (Fraise, 1963).

Most of the studies on the effects of climatic and meteorological conditions have addressed themselves to the evaluation of the effects of extremes of temperature and pressure on the psychological performance and physiological functioning of the human organism. The general setting of such investigations has been the laboratory where the temperature of the surrounds is lowered or raised and the subjects presented with a variety of tasks and tests. A few anecdotal field reports on the adverse effects of temperature, pressure, and lack of oxygen on scientists, servicemen, pilots, and mountaineers, in the Arctic, in a plane at high altitude, or on a 20,000 foot mountain are also on record.

The results of these investigations and observations invariably show that mental and physical performance deteriorates under extreme conditions (Carlson, 1961; Clark, 1961; Clark and Cohen, 1960). Although some studies have failed to find deterioration in performance under exposure to extremes in temperature (Chiles, 1957), such results can probably be attributed to the nature of the participating personnel and the task. Further, it is doubtful that "extremes" of temperature were ever reached.

Despite the abundance of studies on the effects of exposure and adaptation to extremes of heat, cold, pressure, and altitude, studies in which the relationship of moderate fluctuations in meteorological or geophysical conditions to everyday behavior is investigated over a period of time are

few in number. Friedman, Becker, and Bachman (1963) found a slight correlation between psychiatric disturbances, measured in terms of daily admissions to seven New York State hospitals and one V.A. hospital, and magnetic field intensity. The nature of the association remains unclear and unexplained, yet it suggests the plausibility of geophysical parameters affecting behavior, directly or through other agents.

Of particular interest has been the influence of "fohn" weather on several aspects of psychophysiological variables (Muecher and Ungeheuer, 1961; Moos, 1963; Moos, 1964). "Fohn" weather is characterized by dry warm southerly winds in the Alpine regions of Europe. It is accompanied by a drop in atmospheric pressure, a sharp rise in temperature, and a decrease in relative humidity.[1] Under advective changes in weather conditions, Muecher and Ungeheuer found a higher RT threshold, as well as a higher CFF threshold. Moreover, a significant increase in job accidents and dispensary visits on an industrial plant were observed during fohn-like weather conditions. In view of this evidence, the investigators suggest that meteorological factors affect motivation, and psychophysiological performance.

Moos (1963), in his investigations of the effects of "fohn" weather on birth and death rates in the principality of Liechtenstein, found a higher number of births and deaths during "fohn" weather than under normal weather conditions. The predominant cause of death was attributed to chronic or acute cardiovascular malfunctions. In another study, Moos (1964) investigating anecdotal reports that psychophysiological symptoms often preceed the "fohn" itself, reported a significantly larger number of car accidents in Zurich, Switzerland during pre-fohn conditions four hours before the onset of the actual "fohn" weather. Accidents were also higher during the "fohn" itself.

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1. Dordick (1958) indicates that "fohn" weather resembles closely the "Chinook" of the Rocky Mountains.

The present study was undertaken to investigate the effects of a number of meteorological variables, such as temperature, humidity, barometric pressure, wind velocity, on the self-reported psychosomatic state of a group of individuals.

METHOD

Subjects: The subjects were 22 female and 20 male students enrolled in a social psychology class at Texas Christian University in the Spring of 1963. These 42 individuals were present in class at least seventy-five per cent of the time. Data gathered from students not meeting this specification were dropped from consideration.

Instruments: The main inventory used in the study was a check list comprising forty phrases descriptive of various states of subjective feeling (Appendix A). The items were selected from the 74 items of the Feeling and Doing Test developed for the Randolph Field Battery for a research program on the psychiatric selection of Air Force crews (Sells, 1951).

A distinctive feature of this checklist is the instruction, "check every item that reflects how you feel right now." This instruction has been used in previous work by Sells et. al. (1956) and the results show that it is highly appropriate for repetitive testing with a constant inquiry form.

The Cattell 16 PF Questionnaire, Form A, was also utilized.

Procedure: The subjects were asked to fill out the "subjective feeling" inventory at the beginning of each class period. The purpose of the study was not revealed to the Ss. As the class met at 8:00 AM on Mondays, Wednesdays, and Fridays in the months of February, March, April, and May, meteorological observations for these periods were obtained from the U.S. Weather Bureau Station at Southwest International Airport, Fort Worth, Texas.

At the conclusion of the investigation, data had been collected on 37 occasions over a four month period. Towards the end of the study, the subjects were administered the 16 PF Questionnaire.

RESULTS

The correlation of the subjective feeling check list with the second order anxiety factor of the 16 PF Questionnaire was .66 for the female sample and only .09 for the male sample when the mean of the psychosomatic symptoms tallied by the Ss over 37 occasions was considered as their score on the subjective feeling check list. The correlation of the check list with the 16 PF anxiety factor for the entire sample was .37. The relatively large discrepancy in the correlations of the check list with the 16 PF anxiety factor for the two groups differentiated as to sex remains unexplained in the absence of additional data. No significant difference was found in the average number of worries, ailments, moods, and symptoms checked by males and females during the course of the study (chi-square = .954 for median test with 1 df). A tabulation of the frequency of the items tallied by the male and female Ss is presented in Table I.

Correlations between daily mean "subjective-feeling scores" and meteorological variables were obtained for males and females separately, and for the sexes combined. The meteorological variables taken into consideration for the 37 occasions on which data were obtained were the 8:00 AM barometric pressure, the difference between the maximum and minimum barometric pressure for a 24-hour period, the 8:00 AM temperature, the maximum temperature for that day, the minimum temperature for that day, the difference between the maximum and minimum temperatures, the relative humidity, wind velocity, ceiling, sky cover, dew point, and wet bulb temperature at 8:00 AM. The correlations of "subjective feeling" scores of the Ss with the meteorological observations are presented in Table II. Of these correlations only that between wet bulb temperature at 8:00 AM with the mean subjective feeling score for the female sample is significant at the .05 level. The correlation between the 8:00 AM temperature and subjective feeling approaches significance for the female sample and the entire sample suggesting that on colder days subjects tally more items indicative of unpleasant feeling and mood. The correlation of the 8:00 AM temperature with the subjective feeling score of the male sample is in the expected direction but not significant. The relatively

TABLE I

FREQUENCY AND PERCENT OF RESPONSES GIVEN BY MALE AND FEMALE SUBJECTS TO THE FORTY ITEMS OF THE SUBJECTIVE-FEELING INVENTORY ON 37 OCCASIONS

		headache	pressure in head	back of neck stiff and sore	queer unpleasant feelings in body	excessive perspiration	upset stomach	cold hands/or feet	difficulty in concentrating	wet, clammy hands/or feet	dizzyness
	Item	1	2	3	4	5	6	7	8	9	10
Males	Frequency	31	27	28	16	4	21	60	26	10	5
	Percent	2.0354	1.7728	1.8384	1.0505	.2626	1.3788	3.9396	1.7071	.6566	.3283
Females	Frequency	40	19	47	19	5	29	127	66	40	13
	Percent	2.7229	1.2934	3.1994	1.2934	.3404	1.9741	8.6513	4.4928	2.7229	.8850

TABLE I (contin.)

		feel faint	difficulty breathing	heart beats too fast	shaking and trembling	fidgity and restless	excited or nervous	sensitive to noises	jumpy or easily startled	annoyed by loud people	annoyed by grating or repeated sounds
	Item	11	12	13	14	15	16	17	18	19	20
Males	Frequency	0	25	30	19	42	56	47	35	78	48
	Percent	0	1.6414	1.9698	1.2475	2.7577	3.6769	3.0860	2.2980	5.1215	3.1516
Females	Frequency	1	40	11	8	44	65	20	11	16	6
	Percent	.0681	2.7229	.7488	.5446	2.9952	4.4248	1.3615	.7488	1.0892	.4048

TABLE I (contin.)

		ringing or buzzing in ears	mist before eyes	insomnia or sleeplessness	hard time waking up	unpleasant or scary dreams	poor appetite	eat too much	exhausted	tired for no reason at all	worry about health
	Item	21	22	23	24	25	26	27	28	29	30
Males	Frequency	6	8	59	337	15	79	11	60	38	22
	Percent	.3939	.5253	3.8739	22.1274	.9849	5.1871	.7223	3.9396	2.4950	1.4445
Females	Frequency	8	19	44	338	35	41	40	95	28	8
	Percent	.5446	1.2934	2.9952	23.0088	2.3826	2.7910	2.7229	6.4670	1.9061	.5446

TABLE I (contin.)

		worry about the future	worry about money	fearful of accidents	fearful of failure	frustrated or beaten	angry or resentful	sorry for self	wish I were dead	unduly irritable	depressed
	Item	31	32	33	34	35	36	37	38	39	40
Males	Frequency	141	36	11	37	8	7	4	5	11	20
	Percent	9.2580	2.3637	.7223	2.4294	.5253	.4596	.2626	.3283	.7223	1.3132
Females	Frequency	53	11	2	55	10	9	4	0	17	25
	Percent	3.6079	.7488	.1362	3.7440	.6807	.6127	.2791	0	1.1572	1.7018

TABLE II

CORRELATIONS OF THE SUBJECTIVE FEELING INVENTORY WITH DAILY METEOROLOGICAL OBSERVATIONS ON 37 OCCASIONS

Meteorological Variables	r With Daily Mean Subjective Feeling Score for Males	r With Daily Mean Subjective Feeling Score for Females	r With Daily Mean Subjective Feeling Score for the Entire Group
1. Barometric Pressure at 8:00 AM	-.11	.00	-.08
2. Difference in Maximum and Minimum Barometric Pressure	-.21	.22	-.05
3. Temperature at 8:00 AM	-.23	-.31	-.31
4. Daily Maximum Temperature	-.09	-.25	-.19
5. Daily Minimum Temperature	-.23	-.20	-.25
6. Difference in Maximum and Minimum Temperature	.27	-.04	.14
7. Relative Humidity at 8:00 AM	.04	-.11	-.03
8. Wind Velocity at 8:00 AM	.06	-.12	-.01
9. Ceiling at 8:00 AM	-.07	-.07	-.09
10. Sky Cover at 8:00 AM	.15	.02	.13
11. Dew Point at 8:00 AM	-.16	-.30	-.26
12. Wet Bulb Tempt. at 8:00 AM	-.11	.35*	.11

*Significant at .05.

small difference in the magnitude of the correlation of the 8:00 AM temperature with "subjective feeling" in the male and female samples might be attributable to a simple agent such as clothing. The female student seems to be less well protected against the cold in her attire than the male. It may also seem plausible to suggest that a complex biophysiological factor makes the female more sensitive to cold weather. The discrepancy and reversal of sign observed in the correlations of wet bulb temperature with the "subjective feeling" score of the male and female samples is puzzling and remains unexplained.

Although some other weather variables show a certain amount of association with the subjective feeling check list, there is no indication that these small correlations are not random fluctuations from rho = 0.00.

Multiple correlations with the 8:00 AM readings of dry bulb temperature, dew point, wet bulb temperature, sky cover, ceiling, barometric pressure, relative humidity, and the maximum and minimum temperatures for that day as predictors and the mean subjective feeling scores of the male and female samples and the total sample as criterion yielded coefficients of .61, .48, .49 for the respective samples. None of these multiple correlations was significant. Yet, significant multiple correlations were obtained when fewer predictors were taken into consideration. Thus, an R of .61, significant at the .05 level, was attained for the male sample using only five predictor variables: minimum temperature, maximum temperature, and the 8:00 AM readings of sky cover, dry bulb temperature, and dew point. An R of .40, significant at the .05 level, was attained for the female sample when only two predictors were taken into consideration, namely, wet bulb temperature at 8:00 AM and dry bulb temperature at 8:00 AM. For the total sample, at no stage was the multiple correlation found to exceed chance level.

The intercorrelation matrix for the predictors and criterion is given in Table III. The beta weights for the predictors are presented in Table IV

TABLE III

INTERCORRELATION MATRIX OF METEOROLOGICAL PREDICTORS AND THE SUBJECTIVE FEELING SCORE CRITERION

	9 Temp.	8 Dew Point	7 Max. Temp.	6 Min. Temp.	5 Sky Cover	4 Ceiling	3 B. Pressure	2 Humidity	1 Wet Bulb	A "Subj. Feeling" Sc. Male Sample	B "Subj. Feeling" Sc. Female Sample	C "Subj. Feeling" Sc. Total Sample
9		.8951	.8832	.9070	.0534	-.1295	.4075	-.2770	-.3360	-.2287	-.3129	-.3063
8			.6939	.8684	.2246	-.3199	.0923	-.1461	-.3296	-.1614	-.3048	-.2581
7				.8450	-.1927	.1108	.5668	-.4716	-.4005	-.0939	-.2528	-.1859
6					.1270	-.1734	.4182	-.5261	-.2813	-.2344	-.2042	-.2456
5						-.6777	-.1523	-.0334	.0725	.1491	.0246	.1320
4							.1949	-.0749	-.0286	-.0679	-.0714	-.0917
3								-.6999	.0546	-.1118	-.0050	-.0804
2									-.0719	.0412	-.1052	-.0316
1										-.1087	.3468	.1057
A												
B												
C												

TABLE IV

BETA WEIGHTS FOR METEOROLOGICAL VARIABLES PREDICTING "SUBJECTIVE FEELING"

Variable	Male Sample	Female Sample	Total Sample
Temperature 8:00 AM	-1.3985	-.4727	-1.2381
Dew Point	.9291	-.3720	.3537
Maximum Temperature	1.5091	.1850	- .4135
Minimum Temperature	-1.1821	.4631	1.1344
Sky Cover	.4264	-.0654	.2850
Ceiling	- .0470	-.2169	.1198
Barometric Pressure	.0168	-.0590	- .1369
Humidity	- .1012	.0000	- .0203
Wet Bulb	- .0412	.2714	- .0141

DISCUSSION

Because of the small N, 42, and the relatively few occasions on which observations were made, 37, time series analysis, which is more appropriate for a study of this nature, were not applied to the data.

As this study was not conducted within the controlled confine of the laboratory, several extraneous and confounding factors might have been at play. For example, the symptoms of indisposition tallied in the month of May in spite of the sunny and warm weather might be products of the students' apprehension of approaching final examinations and term paper deadlines.

Although one single correlation, namely that between wet bulb temperature and the daily "subjective feeling" score of the female sample is significant, and even though this correlation could have easily occurred by chance, the present writers feel that moderate changes in weather conditions should not account for a substantial amount of variance in human behavior, moods, feelings of malaise, complaints, and ailments, especially where modern day conveniences, such as adequate heating and air-conditioning, are available. Therefore, in a study of this nature, impressive correlations should not be expected. In order to determine whether the correlations in this study were obtained by chance and hence do not signify even the minutest relationship between meteorological variables and feelings of depression, irritability, malaise, and various other symptoms of discomfort and general complaints, replications of the present study need to be carried out. A consistency in the results of several replications would suggest a relationship between meteorological changes and subjective states of the organism.

Moreover, the present writers are of the opinion that in studies of this nature, meteorological measures should not be considered in isolation but that the total weather situation, with concomitant changes in temperature, barometric pressure, humidity, wind velocity, electromagnetic radiation, etc., such as pre-frontal conditions, should be taken into account. Finally an effort should be made to discover the behavioral indices sensitive to changes in weather conditions. Until further studies are carried out the results of the present study have to be regarded as being essentially negative.

Even though the results obtained in this study are by no means strong, clear, conclusive or definitive, the investigators feel that further studies along similar lines might prove fruitful. An investigation with a larger sample, a larger number of occasions, and more refined and sensitive instruments measuring several different aspects of human behavior, and a composite measure depicting the total weather situation, would be a worthwhile undertaking. As a preliminary large scale study the investigators are at present engaged in an analysis of the relationship between police disturbances in the city of Fort Worth and the weather conditions at the time. Some sixty-five thousand police incidents recorded over a five-month period are presently being analyzed for trends concomitant with changes in weather conditions. Several studies, designed with the theoretical orientation expounded in the beginning of this report, might prove fruitful in isolating those variables in our natural environment that sway and actuate some aspects of human behavior to a slight or substantial degree.

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APPENDIX A

SUBJECTIVE FEELING CHECK LIST

Name _____ Date _____

Check every item that reflects how you feel right now.

__ 1. headache
__ 2. pressure in head
__ 3. back of neck stiff and sore
__ 4. queer unpleasant feelings in body
__ 5. excessive perspiration
__ 6. upset stomach
__ 7. cold hands/or feet
__ 8. difficulty in concentrating
__ 9. wet, clammy hands/or feet
__10. dizzyness
__11. feel faint
__12. difficulty breathing
__13. heart beats too fast
__14. shaking and trembling
__15. fidgity and restless
__16. excited or nervous
__17. sensitive to noises
__18. jumpy or easily startled
__19. annoyed by loud people
__20. annoyed by grating or repeated sounds
21. __ ringing or buzzing in ears
22. __ mist before eyes
23. __ insomnia or sleeplessness
24. __ hard time waking up
25. __ unpleasant or scary dreams
26. __ poor appetite
27. __ eat too much
28. __ exhausted
29. __ tired for no reason at all
30. __ worry about health
31. __ worry about the future
32. __ worry about money
33. __ fearful of accidents
34. __ fearful of failure
35. __ frustrated or beaten
36. __ angry or resentful
37. __ sorry for self
38. __ wish I were dead
39. __ unduly irritable
40. __ depressed